# Smart Data Node in the Sky (SDNITS): Communications System

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***Abstract*-The design of the telecommunications network to serve the high data producing, spatially diverse satellites must be defined, so that the high volume of data is conveniently and efficiently transferred to the desired location on ground from a system of satellites. The system consists of multiple satellites in different orbits; these orbits may be circular, elliptical or geo-synchronous in nature. Each of the satellites in the network generates high data volume that needs to be transmitted to the ground station in near real time to be distributed to the users. Each satellite's orbit must be selected so that it supports the maximum science data generation and at the same time helps communications between the satellite and ground. These satellites embody the high data volume science satellites of the future.**

**In this paper we will discuss: the steps for adequately designing such a complex telecommunications system "Smart Data Node In The Sky (SDNITS)"; algorithm development for this process; specifications to be levied on the interfacing subsystems; type of the system e.g., the usual Radio Frequency system or a laser communications system. Within the Radio Frequency system, usual residual or suppressed carrier system or a spread spectrum system would be needed etc. Preliminary design parameter values such as the power amplifier rating, antenna size and slewing, Doppler frequency and rate, ground station antenna slewing and acceleration, visibility times at the ground station and for satellite-satellite communications and overall system performance are also presented in this paper.**

## I. INTRODUCTION

A master satellite that has direct or indirect communications links with all the science satellite will be placed in an orbit that may be circular, elliptical or geo-synchronous. The actual optimal orbit selection involves many parameters of the system. The master satellite gathers the data from all these science satellites and transmits it to the ground station in a predetermined manner. The data transmission from these science satellites to the master could be simultaneous or the master satellite may solicit their transmission on an individual basis. This master satellite is SDNITS.

## II. THEORY

The future trend of the science satellites carrying the instruments such as SARs, Lidars, and Hyperspectral imagers is basically a very high volume of data produced per second. [2] discusses future communications needs in the future. Any satellite used to bring this data down to a ground station must necessarily have an extremely high data rate. Once the data are delivered to the ground high rate fiber optics technology will be used to send it to the users / customers.

The SDNITS satellite may be placed in a LEO (Low Earth Orbit), a MEO (Medium Earth Orbit), a HEO (Highly Eccentric Orbit) or a GEO (Geosynchronous Orbit). Each orbit has its own advantages and advantages as regards to the SDNITS s/c needs. A quick look at the advantages and disadvantages of LEO and GEO tells us MEO and HEO will lie anywhere in between: 1) With the user s/c in a LEO, the visibility of SDNITS s/c in LEO would be very limited and in bursts making high data storage and very high data rates on user satellite necessary compared to SDNITS s/c being in GEO. 2) To make the above visibility time sufficient many more SDNITS would be needed in LEO than the required 3 SDNITS s/c in GEO. 3) With the user s/c and SDNITS s/c in LEO the cross velocity between them would be quite large and would necessitate a very quick and expensive antenna subsystem on both the s/c as opposed to placing SDNITS s/c in GEO. 4) The range between the two s/c placed in LEO would be small compared to when the SDNITS s/c is placed in GEO requiring a larger antenna and more power on the user s/c. 5) Servicing of the SDNITS in LEO would be far simpler and less expensive than having it in GEO. It should be noted that even with the advantages and disadvantages stated above for LEO and GEO, the actual placement will depend upon the values of these parameters.

Max Range Calculations: The range computations as well as all the rest of the computations in this paper will be done for coplanar orbits and coincident semi-major axes. This will provide us with the worst case numbers.

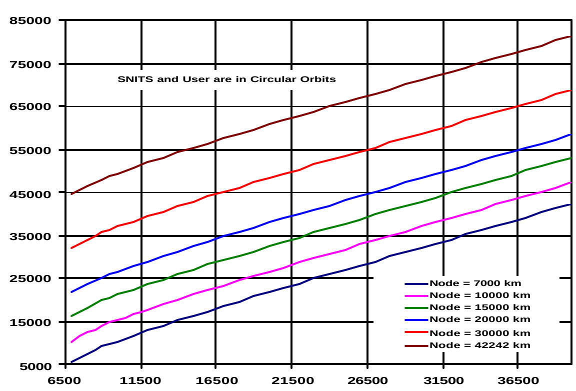


Figure 1. Max user s/c to SDNITS s/c range.

This maximum distance is plotted in Figure 1 as a function of the circular orbit user s/c orbital radius where the SDNITS circular orbit radius is the parameter. It can be seen that the maximum distance belongs to the range of 5000 km to 82000 km. User s/c antenna diameter and the power radiated and the SDNITS s/c antenna diameter should be appropriately designed to counteract the space loss connected with these maximum distances. In a similar manner the maximum range between the SDNITS s/c and the ground station may be computed.

Visibility Calculations: The visibility times are needed for the design of a s/c communications subsystem in terms of required data rate, data storage capacity, antenna and power amplifier sizes for the data transmission. The visibility time also determines time for which the ground station(s) should be commissioned for the mission tracking purpose and hence the cost of the mission. There are two different visibility times of interest, SDNITS s/c-ground station visibility and SDNITS s/c-User s/c visibility. The former depends upon the s/c being pro-grade or retro-grade, the altitude, semi-major axis length, and eccentricity of the s/c. The analysis was done for the co-planar equatorial orbits described above and the ground station was on the equator. The results are plotted in Figure 2 & 3.

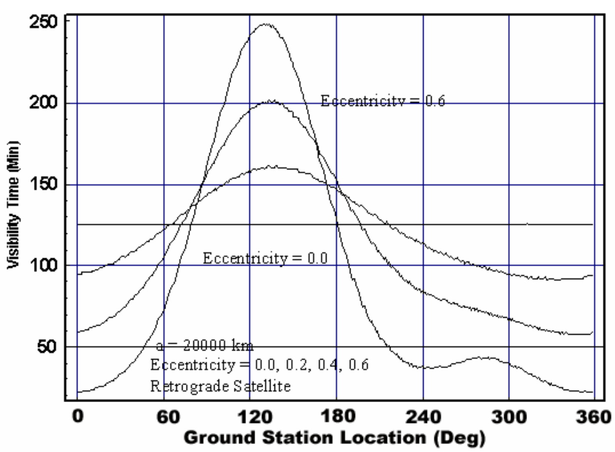


Figure 2. Visibility time for s/c – ground station.

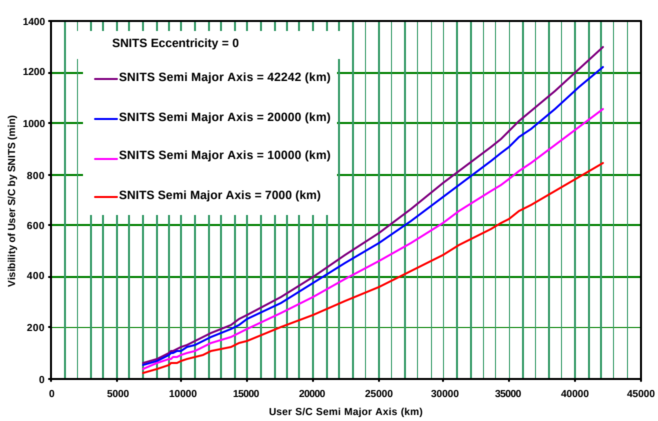


Figure 3. Visibility between two s/c

Basic conclusion from these two figures is that as the altitude of SDNITS s/c increases, larger visibility time intervals are available.

Antenna Foot Print Size: This is another parameter that needs to be understood that has an impact on the operation of the ground station. The analysis was done on the equatorial plane elliptical orbits when the ground station is on the equator.

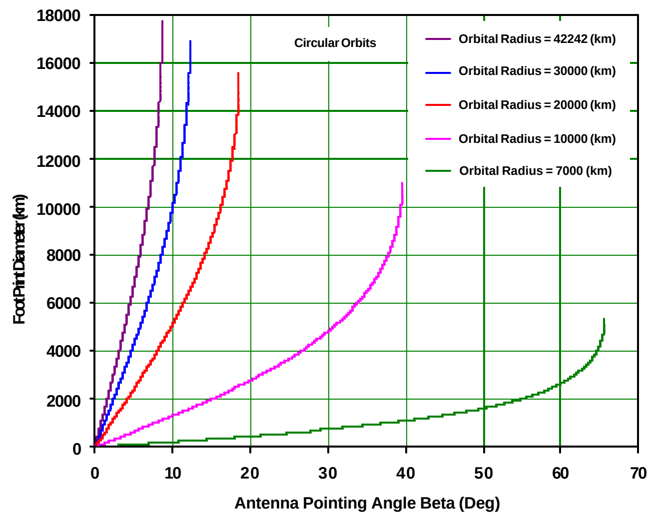


Figure 4. Foot print diameter as a function of the antenna angle.

The figure naturally shows that as the orbital radius increases, the foot print diameter increases linearly first then faster later.

Doppler and Cross Track Velocities: Doppler producing velocity can come from the translational as well as rotational motions of the two satellites. The Doppler effect produced by these motions will affect the telecommunications systems involved unless they are corrected. The major effect would be during the carrier tracking that is needed before the data may be demodulated. The cross velocity produces the angular velocity that affects the antenna pointing system of the user as well as the SDNITS s/c. The analysis was performed on the coplanar orbits as before and the results are shown in Figures 5, and 6.

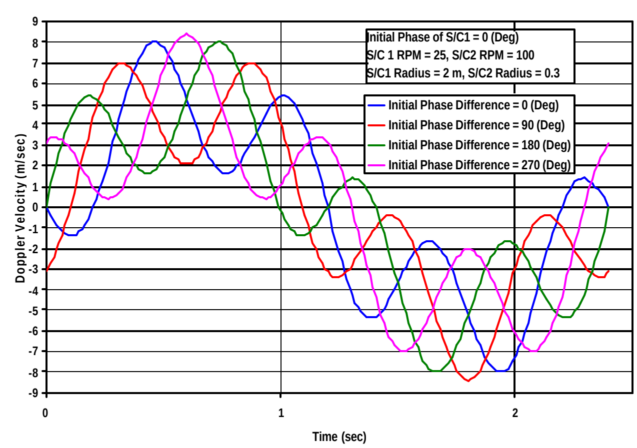


Figure 5. Rotational Doppler velocity between two s/c

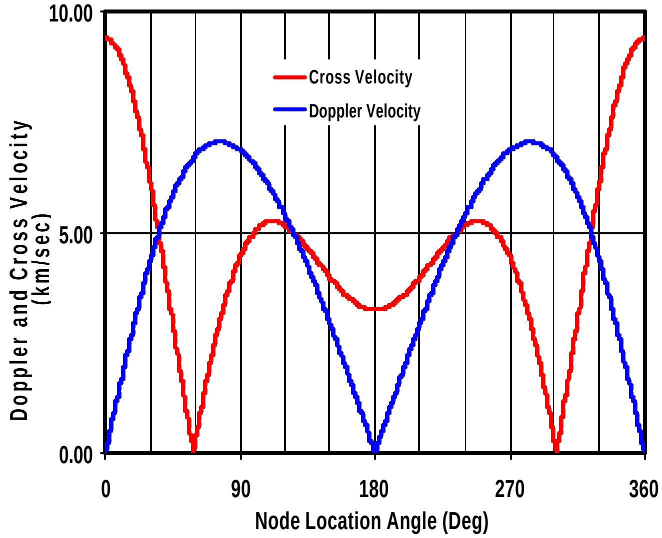


Figure 6. Doppler and cross velocity between s/c.

<u>SDNITS Telecom System Design:</u> Suppose the SDNITS spacecraft is orbiting in a GEO orbit and the user is in a LEO with an altitude of 7000 km. Both orbits are circular in nature (i.e., eccentricities of both the orbits = 0). Following table shows a probable design using Ka band. This design uses the analysis done before.

Table 1. Ka-Band Telecom Design.

| **Desired Parameters** | |
|---|---|
| Desired data rate | 1 Gbps |
| User altitude (circular orbit) | 7000 km |
| SDNITS altitude (circular orbit) | 42242 km (GEO) |
| Desired bit rate of the link | 1 Gbps |
| Desired frequency of the link. (Ka-Band) | 32000 MHz |
| **Calculated Parameters** | |
| Max SDNITS-User s/c range. | 44642 (km) |
| Total EIRP for desired 1 Gbps data rate. | 106 (dBW) |
| SDNITS antenna Gain | 60 (dB) |
| SDNITS antenna diameter required. | 4 m |
| User satellite antenna EIRP. | 46 (dBW) |
| User satellite transmitted power. | 20 (W) |
| User satellite antenna diameter required. | 0.8 m |

- Frequency used will be in the Ka-Band. The gain of the antenna would be about 60 dB or so at this frequency.
- The antenna will form multiple beams to cover desired region.
- The SDNITS will use spread spectrum direct sequence method of communications. All user s/c will use a standard transponder.
- The antenna will be pointed towards earth's center.
- Total number of beams will be selected so that adequate gain is available for each and every user.

Figure 8 shows the number of the beams from the SDNITS s/c to cover all the s/c depending on the maximum distance of the user s/c set from the SDNITS s/c. The spread spectrum will be affected using the Gold Codes that will not only spread the signal but also identify the user. The SDNITS will downlink all the data from every user using a laser communications link shown in Figure 7. As a backup against the weather (rain, clouds, etc.) there will be a Ka-Band RF link also.

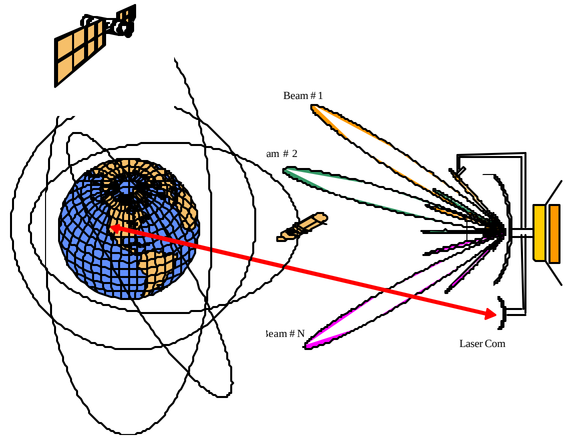


Figure 7 A possible SDNITS realization.

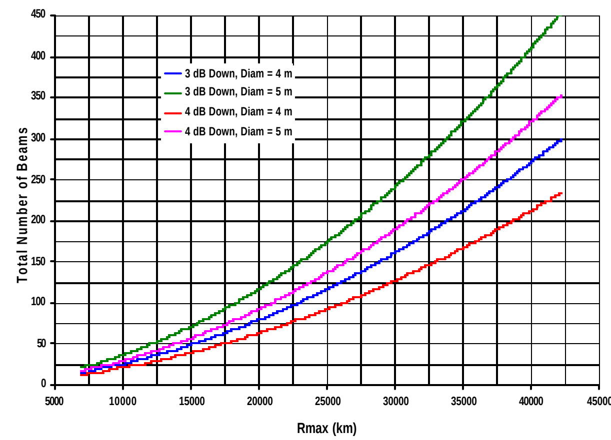


Figure 8 Number of beams as a function of Max range.

## III. CONCLUSIONS

This paper presents a unique concept of a new high data rate satellite system employing spread spectrum communications that offers many benefits over the currently existing high data rate systems. It would take 3 such satellites to cover the globe to offer continuous service for any user(s).

## IV. ACKNOWLEDGEMENT

Faiza Lansing thanks Mr. Casey Heeg for his assistance in producing a movie to visualize this concept.

The research described in this paper was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

## V. REFERENCES

[1] Faiza Lansing and Anil V. Kantak "Smart Data Node In The Sky". JPL Internal Report, December 10, 2002.

[2] Faiza Lansing, et al, "Needs for Communications and Onboard Processing in the Vision Era", IGARSS Conference, Toronto, Canada, June 2002.